Self-organized growth of dendrite domains in lithium niobate and lithium tantalate single crystals

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The various realizations of surface shape instabilities in non-equilibrium systems leading to formation of self-organized non-equilibrium complicated patterns can be used as potential bottom-up technologies for fast and parallel creation of functional nanostructures. Among them the dendrite patterns being one of the most symmetric and organized structures formed by branching mechanism attract growing attention during last decades [1,2]. It should be noted that existence of similar dendrite patterns can be observed in various physical systems indicating that the common underlying formation mechanisms of such structures exist. The examples of the systems are snowflake growth [2] and air displacement of viscous liquid in Hele-Shaw cell [1].

In this work we present the study of formation and growth of dendrite ferroelectric domains in lithium niobate (LN) and lithium tantalate (LT) single crystals in uniform electric field. Two conditions are required: the domain wall shape instability caused by bulk screening retardation and stochastic nucleation [3-5]. We have realized these conditions by polarization reversal at high temperatures in the plates covered by artificial dielectric layer.

The dendrite domain growth was studied by *in situ* optical visualization during polarization reversal at 250°C in the polar-cut plates of congruent LN and LT crystals covered by silicon dioxide film under transparent indium tin oxide electrodes. The main stages of domain structure evolution have been revealed. The increase of the branch diameter before tip splitting and step-like increase of the branch growth velocity after splitting were observed. Analysis of the static domain structures has allowed obtaining the field dependence of the domain envelop shape and filling ratio. The envelop shape changed from triangular to hexagonal and the filling ratio (ratio of domain and its envelop areas) increased with field increase. The visualization of the domain structure in the bulk by second harmonic generation microscopy allowed measuring of the dendrite structure depth – about 10 μm. The qualitative change of domain shape was revealed at the depth about 150 μm from polar surface. In congruent LT the envelop shape of dendrite domains transformed from triangular to strongly rounded hexagonal shape with increase of the external field.

The phase-field simulation was used to verify the analogy between self-organized growth of dendrite domains and dendrite crystals during the first order phase transition taken into account the crystal symmetry C_{3v} [6]. The similarity of simulated and experimentally observed domain shapes was achieved. The phase diagram of growth domain morphology was constructed by computer simulation.

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